ISSN 2348 – 7968

Design of a Stochastic Forecasting Model for Egg Production

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ABSTRACT

The egg has a very well balanced amino acid profile with the required minerals and vitamins. This paper deals with the design of the stochastic modeling for egg production forecasting in Tamilnadu, based on data on egg production during the years from 1996 to 2008. The study considered Autoregressive (AR), Moving Average (MA) and Autoregressive Integrated Moving Average (ARIMA) processes to select the appropriate stochastic model for egg production forecasting in Tamilnadu. Based on ARIMA (p, d, q) and its components ACF, PACF, Normalized BIC, Box-Ljung Q statistics and residuals estimated, ARIMA (0, 1, 1) was selected. Based on the chosen model, it could be predicted that the egg production would increase to 19,179 millions in 2015 from 8,960 millions in 2008 in Tamilnadu.

Keywords: Egg production, BIC, forecasting, ARIMA.

INTRODUCTION

Egg is food materials universally acceptable without being forbidden by any religious taboos. Egg is the cheapest food sources of animal protein. The egg has a very well balanced amino acid profile with the required minerals and vitamins. Unlike other animal fats, egg lipids are not fats; but oils good for health; they contain more omega-9 fatty acid-MUFA which increases the good HDL-cholesterol in the serum. Moreover, they contain considerable amounts of omega-3 fatty acids (N-3 PUFA) which reduces the serum bad LDL-cholesterol. Hence the egg and chicken lipids are good for health. Tamilnadu is one of the leading States in egg production and export. The eco-friendly backyard poultry rearing is practiced along with commercial poultry farming in the State. The egg production in the State which improved from 3784 million numbers in 2003-04 to 6395 million numbers in 2004-05 marginally declined to 6223 million numbers in 2005-06. Consequently the per capita availability of egg per annum has declined from 102 numbers. In this background, this study was conducted to forecast the future egg production in the State, so as to help the policy planners to formulate needed strategies for achieving and sustaining the targets in the sector.

MATERIAL AND METHODS

As the aim of the study was to forecast egg production, various forecasting techniques were considered for use. ARIMA model, introduced by Box and Jenkins (1970), was frequently used for discovering the pattern and predicting the future values of the time series data. Akaike (1970) discussed the stationary time series by an AR(p), where p is finite and bounded by the same integer. Moving Average (MA) models were used by Slutzky (1973). Hannan and Quinn (1979) suggested obtaining the order of a time series model by minimizing the errors for pure AR models, and Hannan (1980) for ARMA models. A second order determination method could be considered as a variance of Schwarz's Bayesian Criterion (SBC) which gives a consistent estimate of the order of an ARMA model. Hosking (1981) introduced a family of models, called fractionally differenced autoregressive integrated moving average models, by generalizing the 'd' fraction in ARIMA (p, d, q) model. Jai Sankar et al. (2010) used stochastic modeling for cattle production and forecast the yearly production of cattle in the Tamilnadu state during 1970-2010. Jai Sankar et al. (2011) also used stochastic modeling for bovine production and forecast the yearly production.

Stochastic time-series ARIMA models were widely used in time series data having the characteristics (Alan Pankratz, 1983) of parsimonious, stationary, invertible, significant estimated coefficients and statistically independent and normally distributed residuals. When a time series is non-stationary, it can often be made stationary by taking first differences of the series i.e., creating a new time series of successive differences (Y_t-Y_{t-1}). If first differences do not convert the series to stationary form, then first differences can be created. This is called second-order differencing. A distinction is made between a second-order differences (Y_t-Y_{t-2}).

While Mendelssohn (1981) used Box-Jenkins models to forecast fishery dynamics, Prajneshu and Venugopalan (1996) discussed various statistical modeling techniques viz., polynomial, ARIMA time series methodology and nonlinear mechanistic growth modeling approach for describing marine, inland as well as total fish production in India during the period 1950-51 to 1994-95. Tsitsika *et al.* (2007) also used univariate and multivariate ARIMA models to model and forecast the monthly pelagic production of fish species in the Mediterranean Sea during 1990-2005.

The time series when differenced follows both AR and MA models and is known as autoregressive integrated moving averages (ARIMA) model. Hence, ARIMA model was used in this study, which required a sufficiently large data set and involved four steps: identification, estimation, diagnostic checking and forecasting. Model parameters were estimated using the Statistical Package for Social Sciences (SPSS) package and to fit the ARIMA models.

Autoregressive process of order (p) is, $Y_t = \mu + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + ... + \phi_p Y_{t-p} + \varepsilon_t$;

Moving Average process of order (q) is, $Y_t = \mu - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - .... - \theta_q \varepsilon_{t-q} + \varepsilon_t$;

and the general form of ARIMA model of order (p, d, q) is

$$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + ... + \phi_p Y_{t-p} + \mu - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - .... - \theta_q \varepsilon_{t-q} + \varepsilon_t$$

where Y_t is egg production export, ε_t's are independently and normally distributed with zero mean and constant variance σ^2 for t = 1,2,..., n; d is the fraction differenced while interpreting AR and MA and ϕs and θs are coefficients to be estimated.

Trend Fitting**:** The Box-Ljung Q statistics was used to transform the non-stationary data in to stationarity data and to check the adequacy for the residuals. For evaluating the adequacy of AR, MA and ARIMA processes, various reliability statistics like R^2, Stationary R^2, Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), and Bayesian Information Criterion (BIC) [as suggested by Schwartz, 1978] were used. The reliability statistics viz. RMSE, MAPE, BIC and Q statistics were computed as below:

$$RMSE = \left[\frac{1}{n} \sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2 \right]^{1/2}$$

$$MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{(Y_i - \hat{Y}_i)}{Y_i} \right|$$

BIC(p,q) = ln v*(p,q) + (p+q) [ln (n) / n]

where p and q are the order of AR and MA processes respectively and n is the number of observations in the time series and v* is the estimate of white noise variance σ^2.

$$Q = \frac{n(n+2) \sum_{i=1}^{k} rk^2}{(n-k)}$$

where n is the number of residuals and rk is the residuals autocorrelation at lag k.

In this study, the data on egg production in Tamilnadu were collected from the Department of Animal Husbandry and Veterinary Services, Government of Tamilnadu for the period from 1996 to 2008 and were used to fit the ARIMA model to predict the future egg production.

RESULTS AND DISCUSSION

Model Identification**:** ARIMA model was designed after assessing that transforming the variable under

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forecasting was a stationary series. The stationary series was the set of values that varied over time around a constant mean and constant variance. The most common method to check the stationarity is to explain the data through graph and hence is done in Figure 1.

Figure 1 reveals that the data used were non-stationary. Again, non-stationarity in mean was corrected through first differencing of the data. The newly constructed variable Y_t could now be examined for stationarity. Since, Y_t was stationary in mean, the next step was to identify the values of p and q. For this, the autocorrelation and partial autocorrelation coefficients (ACF and PACF) of various orders of Y_t were computed and presented in Table 1 and Figure 2.

Figure 1. Time plot of egg production in Tamilnadu

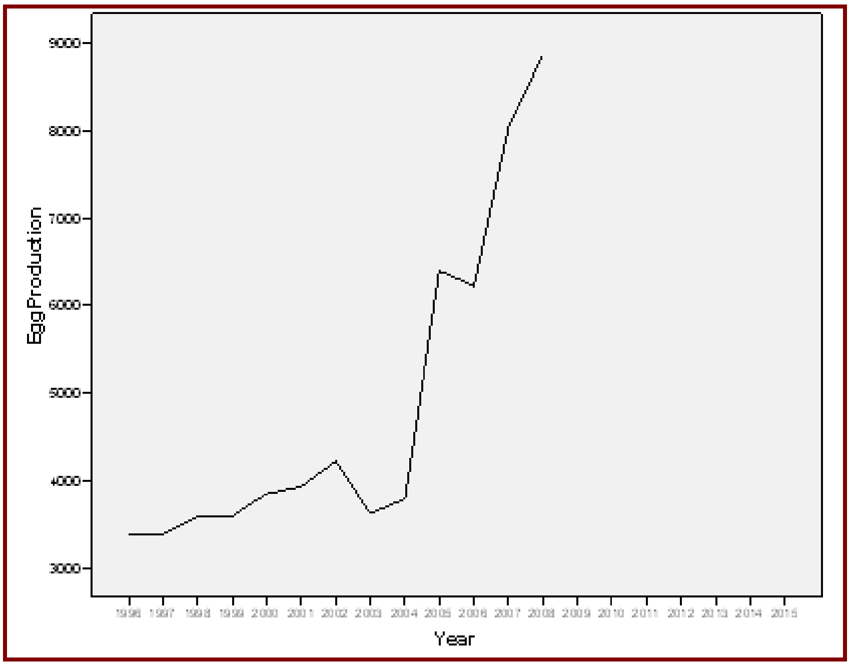

Table 1. ACF and PACF of egg production

Lag	Auto Correlation		Box-Ljung Statistic			Partial Auto Correlation	
	Value	Df	Sig.	Value	Df	Value	Df
1	-0.159	0.256	0.386	-0.159	0.256	-0.159	0.289
2	0.170	0.244	0.872	0.170	0.244	0.149	0.289
3	0.142	0.231	1.250	0.142	0.231	0.198	0.289
4	-0.169	0.218	1.849	-0.169	0.218	-0.157	0.289
5	-0.036	0.204	1.879	-0.036	0.204	-0.158	0.289
6	-0.098	0.189	2.150	-0.098	0.189	-0.102	0.289
7	-0.062	0.173	2.280	-0.062	0.173	0.002	0.289
8	-0.166	0.154	3.431	-0.166	0.154	-0.152	0.289
9	-0.027	0.134	3.472	-0.027	0.134	-0.077	0.289
10	-0.078	0.109	3.983	-0.078	0.109	-0.065	0.289

Figure 2. ACF and PACF of differenced data

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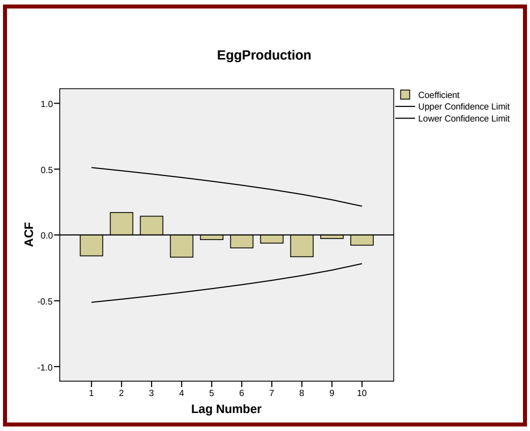
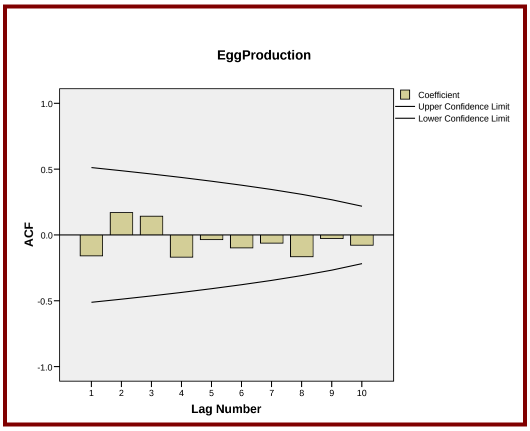




The tentative ARIMA models are discussed with values differenced once (d=1) and the model which had the minimum normalized BIC was chosen. The various ARIMA models and the corresponding normalized BIC values are given in Table 2. The value of normalized BIC of the chosen ARIMA was 13.713.

Table 2. BIC values of ARIMA (p, d, q)

ARIMA (p, d, q)	BIC values
(0, 1, 0)	13.868
(0, 1, 1)	**13.713**
(0, 1, 2)	14.029
(1, 1, 0)	13.934
(1, 1, 1)	14.031
(1, 1, 2)	14.375
(2, 1, 0)	14.228
(2, 1, 1)	14.372
(2, 1, 2)	14.733

Model Estimation**:** Model parameters were estimated using SPSS package and the results of estimation are presented in Tables 3 and 4. R^2 value was 0.89. Hence, the most suitable model for egg production was ARIMA (0, 1, 1), as this model had the lowest normalized BIC value, good R^2 and better model fit statics (RMSE and MAPE).

Table 3. Estimated ARIMA model of egg production

	Estimate	SE	t	Sig.
Constant	-232817.421	61038.718	-3.814	0.004
MA 1	0.984	4.605	0.214	0.836

Table 4. Estimated ARIMA model fit statistics

Fit Statistic	Mean
Stationary R-squared	0.510
R-squared	0.893
RMSE	696.300
MAPE	11.033
Normalized BIC	13.713

Diagnostic Checking**:** The model verification is concerned with checking the residuals of the model to see if they contained any systematic pattern which still could be removed to improve the chosen ARIMA, which has been done through examining the autocorrelations and partial autocorrelations of the residuals of various orders. For this purpose, various autocorrelations up to 11 lags were computed and the same along with their significance tested by Box-Ljung statistic are provided in Table 5. As the results indicate, none of these autocorrelations was significantly different from zero at any reasonable level. This proved that the selected ARIMA model was an appropriate model for egg production in Tamilnadu.

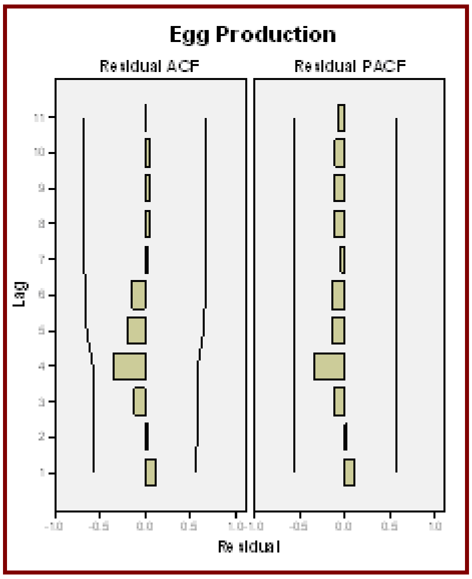
Table 5. Residual of ACF and PACF of egg production

Lag	ACF		PACF	
	Mean	SE	Mean	SE
Lag 1	0.106	0.106	0.106	0.289
Lag 2	0.029	0.029	0.018	0.289
Lag 3	-0.121	-0.121	-0.127	0.289
Lag 4	-0.360	-0.360	-0.344	0.289
Lag 5	-0.194	-0.194	-0.149	0.289
Lag 6	-0.146	-0.146	-0.142	0.289
Lag 7	0.024	0.024	-0.044	0.289
Lag 8	0.051	0.051	-0.126	0.289
Lag 9	0.048	0.048	-0.128	0.289
Lag 10	0.050	0.050	-0.111	0.289
Lag 11	0.013	0.013	-0.081	0.289

The ACF and PACF of the residuals are given in Figure 3, which also indicated the 'good fit' of the model. Hence, the fitted ARIMA model for the egg production data was:

$$Y_t = -232817.421 - 0.984\varepsilon_{t-1} + \varepsilon_t$$

Figure 3. Residuals of ACF and PACF



***Forecasting*:** Based on the model fitted, forecasted egg production (in millions) for the year 2009 through 2015 respectively were 9737, 11019, 12418, 13933, 15565, 17314 and 19179 millions (Table 6). To assess the forecasting ability of the fitted ARIMA model, the measures of the sample period forecasts' accuracy were also computed. This measure also indicated that the forecasting inaccuracy was low. Figure 4 shows the actual and forecasted value of egg production (with 95% confidence limit) in the State.

Table 6. Forecast of egg production (in million) in Tamilnadu

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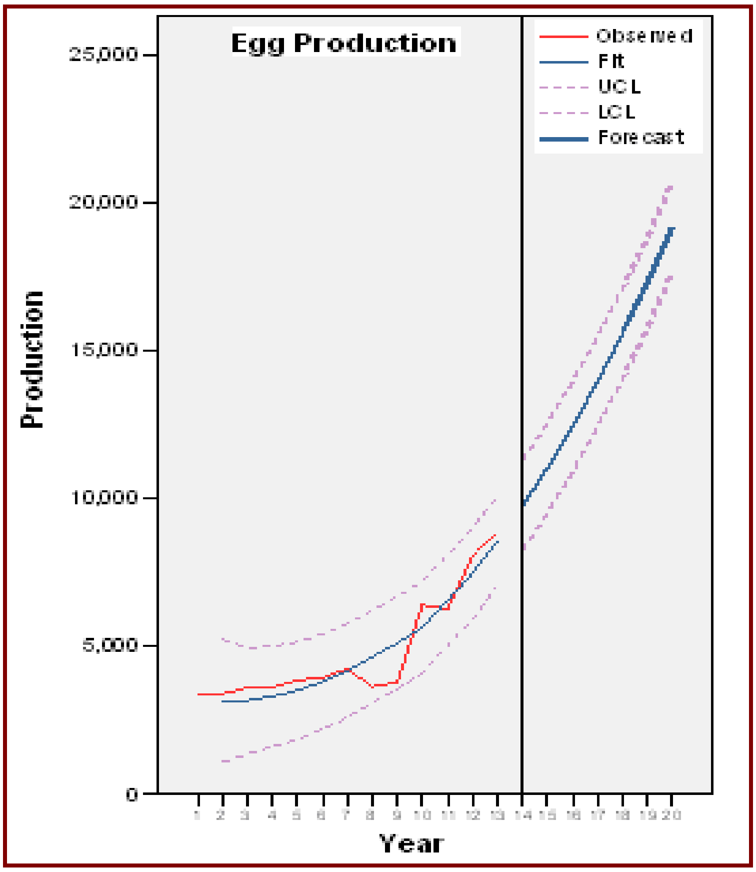
Year	Actual	Predicted	LCL	UCL
1996	3371	--	--	--
1997	3388	3139	1063	5216
1998	3584	3149	1350	4947
1999	3588	3295	1599	4991
2000	3845	3486	1844	5128
2001	3929	3792	2183	5401
2002	4223	4166	2580	5753
2003	3622	4641	3071	6212
2004	3784	5097	3539	6655
2005	6395	5651	4102	7199
2006	6223	6542	5001	8083
2007	8044	7446	5912	8981
2008	8860	8546	7017	10075
2009	--	9737	8212	11261
2010	--	11019	9494	12544
2011	--	12418	10893	13943
2012	--	13933	12409	15458
2013	--	15565	14042	17089
2014	--	17314	15792	18836
2015	--	19179	17657	20700

Figure 4. Actual and estimate of egg production



CONCLUSION

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The most appropriate ARIMA model for egg production forecasting was found to be ARIMA (0, 1, 1). From the forecast available from the fitted ARIMA model, it can be found that the egg production would increase to 19,179 millions in 2015 from 8,960 millions in 2008 in Tamilnadu. That is, using time series data from 1996 to 2008 on egg production, this study provides evidence on future egg production in the State, which can be considered for future policy making and formulating strategies for augmenting and sustaining egg production in the State.

REFERENCES

Akaike H. 1970. Statistical Predictor Identification. *Annals of Institute of Statistical Mathematics* **22**: 203-270.

Alan Pankratz. 1983. Forecasting with univariate Box–Jenkins models - concepts and cases. John Wiley, New York, Page 81.

Box G E P and Jenkins J M. 1970. Time Series Analysis - Forecasting and Control. Holden-Day Inc., San Francisco.

Hannan E J and Quinn B G. 1979. The determination of the order of an autoregression. *Journal of Royal Statistical Society* **B**(41): 190-195.

Hannan E J. 1980. The estimation of the order of an ARMA process. *Annuals of Statistics* **8**: 1071-1081.

Hosking J R M. 1981. Fractional differencing. *Biometrika* **68**(1): 165-176.

Jai Sankar, Prabakaran R, Senthamarai Kannan K and Suresh S. 2010. Stochastic Modeling for Cattle Production Forecasting. *International Journal of Modern Mathematics and Statistics* **4**(2): 53-57.

Jai Sankar, Prabakaran R, Senthamarai Kannan K and Suresh S. 2011. Stochastic Modeling for Bovine Production Forecasting. *International Journal of Agricultural and Statistical Sciences* **7**(1): 141-148.

Mendelssohn R. 1981. Using Box-Jenkins models to forecast fishery dynamics: identification, estimation and checking. *Fishery Bulletin* **78**(4): 887-896.

Prajneshu and Venugopalan R. 1996. Trend analysis in all India marine products export using statistical modeling techniques. *Indian Journal of Fisheries* **43**(2): 107-113.

Slutzky E. 1973. The summation of random causes as the source of cyclic processes. *Econometrica* **5**:105-146.

Tsitsika E V, Maravelias C D and Haralabous J. 2007. Modeling and forecasting pelagic fish production using univariate and multivariate ARIMA models. *Fisheries Science* **73**: 979-988.